



NASA STTR 2006 Phase I Solicitation

T5.02 Impact Detection and Evaluation for Man-Rated Space Vehicles

Lead Center: JSC

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There is significant risk to manned missions from ascent, orbital and interplanetary debris sources. Various NASA programs have chosen to treat the ascent debris and Micro-meteoroid and Orbital Debris (MMOD) impact risk with different intensity and concern. Since the STS-107 accident, NASA has become more concerned about understanding and compensating for this threat. This requires (1) predicting and correlating impacts with structural damage levels; (2) predicting and correlating impact damage levels with structural-dynamic/shock wave responses; (3) efficient systems for detecting, locating and quantifying impacts; (4) inspecting, repairing and performing Non-Destructive Evaluation (NDE) on damaged areas; and (5) efficient systems for detecting, locating and quantifying leaks to vacuum. The scope includes direct application of technology and techniques to Space Shuttle, International Space Station Modules, Inflatable-rigidizable habitats and structures, and Constellation Program man-rated vehicles. Critical areas, such as thermal protection systems and pressurized modules are of primary concern. Awareness of current, state-of-the-art methods and technologies available to and/or applied by NASA is important. Technology development areas are as follows:

Debris impact structural modeling and damage prediction: The developer will use impact test data and design/materials properties to develop models that predict under what conditions impacts will cause damage and what is the extent of the damage. Certain existing flight and ground test data and current analytical techniques can be made available.

- Space Shuttle and International Space Station - develop modeling improvements to critical areas of Orbiter thermal protection system which can more accurately predict failure modes and levels of damage for various ascent debris and MMOD in low Earth orbit.(Orbiter - ascent and on-orbit, ISS on-orbit only).
- Inflatable-rigidizable habitats and structures - develop methods to model potential damage from ascent vibration, earth orbit MMOD and/or lunar surface applications for various candidate inflatable structural material configurations and suggest improvements which reduce risk of damage, more observable damage signatures, incorporate weight savings or other benefits, such as thermal insulation, radiation protection, or longer life. Impact modeling for lunar surface applications will include analysis of free-standing, shielded (separately deployed "umbrella") and covered (layers of regolith for protection).

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- Constellation Program vehicles - develop and evaluate structural models of various candidate and actual vehicle concepts as they evolve for their susceptibility to damage from ascent and Earth orbit MMOD impacts as well as trans-lunar, lunar surface, and trans-Martian impacts.

Debris impact structural-dynamic/shock wave modeling for detection, location and quantification potential for damage: Analytical routines and techniques to optimize prediction accuracy and decrease uncertainties using impact test data, actual flight data, existing and proposed sensor systems and modeling will be developed. Each type of structure in item is a candidate for either improvements in existing structural-dynamic and shock wave prediction models (Space Shuttle Orbiter and International Space Station) or development of these models (inflatable habitats/structures and Constellation vehicles). Limited ground test and flight data can be made available for some structures, but proposals that include instrumented impact testing are encouraged which validate proposed modeling techniques.

Debris impact sensors/sensing systems for critical areas: The developer will recommend practical sensor system solutions for future installations to not only provide impact detection, location and quantification of damage, but also to validate structural models. The sensor/system solutions must account for optimizing the typical factors for space missions: system cost, weight, performance, power, integration, operations time, complexity/reliability, reconfigurability/maintainability, autonomy from Earth-based support, etc. Sensing systems should reduce the vehicle and communication architecture overhead needed for functional redundancy and reliability by considering methods to store and process impact data such that answers are the primary information needed to be transferred within the vehicle but raw data is available on request. No-power Radio Frequency Identification (RFID)-like sensors, very low power standalone sensor systems with scavenge or very long-life power sources, remote sensors and various embedded sensors with a minimum of wired interfaces are examples of what is desired. Other non-contact systems, such as visible or IR flash detection or higher frequency radio frequency (RF) pulse detection may be investigated.

Debris impact structural damage NDE evaluation away from Earth (internal or external environments): Systems and techniques will be developed and tested that can be readily used by astronauts or mobile/robotic systems to evaluate impact-damaged areas and subsequent repairs. Tools and equipment that can provide adequate inspection in hard-to-access areas internally and externally will be especially helpful if it can provide position-awareness of the sensor with respect to the vehicle. Simple human operator interfaces and remote access to data should be considered. NDE systems such as high frequency 3-d imaging, infra-red imagers, eddy current and ultrasound systems will need to be evaluated for their effectiveness on new structural composites, inflatable and rigidizable structures - practically applied in both internal and external evaluations. Certain structural health monitoring needs may require remotely operated NDE systems for periods when the vehicles listed above are not man-tended.

Debris impact structural leaks to vacuum detection, location, quantification and repair: The systems must monitor the pressurized vehicle integrity such that catastrophic leaks can be immediately dealt with to provide crew safety and, for smaller leaks, be sensitive enough to avoid loss of precious air resources to vacuum. Low weight, self-sealing structural concepts will be developed that minimize the air lost, but still are able to be located after the sealing has been accomplished for NDE evaluation. Test-validated models of both structural and airborne ultrasonic propagation of sound in the above pressurized modules, as well as sensing above typical background levels will be important to resolving these issues. Systems should be responsive to some or all levels of impact and leak indications through the rate of pressure loss detected requiring:

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- Immediate location and isolation with limited access to the evacuated module afterward;
 - Limited time to locate and plug the leak; and
 - Extended period to locate, inspect, plan and effect repair and perform NDE afterward.